by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0071] **FIG. 1** is a schematic diagram illustrating a known Electronic Unit Injector system,

[0072] **FIG. 2** is a schematic diagram illustrating a known common rail fuel injection system,

[0073] **FIG. 3** is a schematic diagram of a first embodiment of a fuel injection system in accordance with one aspect of the present invention, and in which the system is in a first operating state,

[0074] **FIG. 4** shows the fuel injection system in **FIG. 3** when in a second operating state,

[0075] **FIG. 5** shows the fuel injection system in **FIGS. 3 and 4** when in a third operating state,

[0076] **FIG. 6** is a graph showing a fuel injection characteristic that is obtainable using the fuel injection system in FIGS. **3** to **5**,

[0077] **FIG. 7** is another graph showing an alternative fuel injection characteristic which is obtainable using the fuel injection system of FIGS. **3** to **5**,

[0078] **FIG. 8** is schematic diagram to illustrate an alternative embodiment of the fuel injection system to that shown in FIGS. **3** to **5**,

[0079] **FIG. 9** is a sectional view of a three position valve for use in a further alternative embodiment of the fuel injection system,

[0080] **FIG. 10** is a schematic view of the valve in **FIG. 9** to show its three operating positions,

[0081] **FIG. 11** is an enlarged sectional view of the three-position valve in **FIGS. 9 and 10**, with an insert showing seatings of the valve in enlarged detail,

[0082] **FIG. 12** is a further alternative embodiment of the fuel injection system incorporating a high pressure shut off valve,

[0083] **FIG. 13** is a schematic view of the high pressure shut off valve arrangement in the embodiment of **FIG. 12**,

[0084] **FIG. 14** is a schematic view of an alternative shut off valve member for us in the shut off valve arrangement in **FIG. 13**, and

[0085] **FIG. 15** shows a sectional view of one practical embodiment of the fuel injection system described with reference to FIGS. **3** to **13**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0086] By way of background to the present invention, **FIGS. 1 and 2** show known Electronic Unit Injector (EUI) and common rail fuel systems respectively. Referring to **FIG. 1**, a known EUI arrangement **10** includes an injector **12** and a high pressure fuel line **14** for providing a supply of fuel at high pressure to an injection nozzle **13** of the injector **12**. A control valve means, typically in the form of a nozzle control valve **16** (alternatively referred to as a needle control valve), is arranged to control movement of a fuel injector valve needle (not shown) so as to control the delivery of fuel from the injection nozzle **13**. The valve needle is engageable with a valve needle seating and movement of the valve needle away from the seating permits fuel to flow through one or more outlets of the injection nozzle **13** into the associated engine cylinder or other combustion space.

[0087] The nozzle control valve **16** is arranged within a further passage **20** in communication with the supply line **14** to control communication between the high pressure supply line **14** and an injector control chamber (not shown). A surface of the valve needle is exposed to fuel pressure within the control chamber, and the pressure of fuel within the control chamber applies a force to the valve needle which serves to urge the valve needle against its seating.

[0088] The nozzle control valve **16** is movable between a first position and a second position. When the nozzle control valve **16** is in the first position, the further passage **20** communicates with the control chamber of the injector **12** and high fuel pressure within the chamber acts on the valve needle surface. When the nozzle control valve **16** is in the second position, the control chamber communicates with a low pressure reservoir (not shown) and communication between the further passage **20** and the control chamber is broken, and the pressure of fuel within the control chamber acting on the valve needle surface is reduced. Operation of the nozzle control valve **16** to control fuel pressure within the control chamber therefore provides a means of controlling valve needle movement towards and away from its seating.

[0089] The EUI **10** also includes a pump, referred to generally as **23**, having a pumping element or plunger **26** and a pump chamber **24**. The plunger **26** is movable within a plunger bore under the influence of a cam drive arrangement, including a cam **28**, so as to pressurise fuel within the pump chamber **24**. The pump chamber **24** communicates with the high pressure fuel line **14** and with a low pressure fuel reservoir (not shown), through an additional passage **30**, under the control of a spill valve **32**.

[0090] In use, rotation of a cam **28** serves to urge the plunger **26** inwardly within its bore to reduce the volume of pump chamber **24**. When the spill valve **32** is in an open position, the pump chamber **24** communicates with the low pressure fuel reservoir so that the pressure in the pump chamber **24** is not substantially affected by movement of the plunger **26** and fuel is simply drawn into and displaced from the pump chamber **24** as the plunger **26** reciprocates. Closure of the spill valve **32** causes fuel pressure within the pump chamber **24** to rise as the plunger **26** is driven inwardly within its bore to reduce the volume of the pump chamber **24**. During the stage of operation in which fuel within the pump chamber is at a high pressure level, the nozzle control valve **16** is then operated to commence injection.

[0091] **FIG. 2** shows a known common rail fuel system including a plurality of fuel injectors **12***a*, **12***b* (two of which are shown), each having an associated nozzle control valve, **16***a*, **16***b* respectively and an associated high pressure fuel supply passages, **14***a*, **14***b* respectively, in communication with an accumulator volume in the form of a common rail **42**. The common rail **42** is supplied with high pressure fuel from a common rail fuel pump **44** and provides an accumulated store of fuel for supply to all of the injectors of the fuel system. In use, the timing of injection of pressurised